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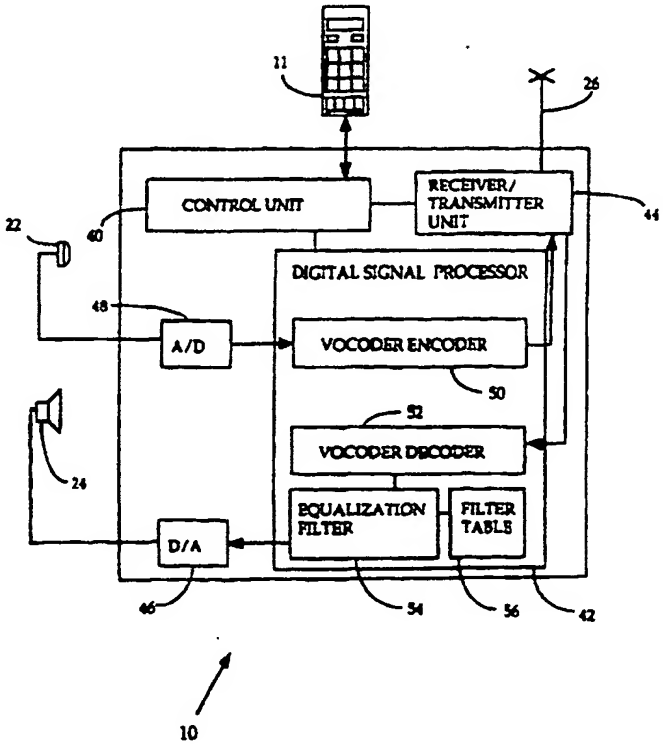
(54) Title: METHOD AND APPARATUS FOR APPLYING A USER SELECTED FREQUENCY RESPONSE PATTERN TO AUDIO SIGNALS PROVIDED TO A CELLULAR TELEPHONE SPEAKER

(57) Abstract

The cellular telephone (10) includes an equalization filter (54) for adjusting the frequency response pattern of an audio signal provided to the speaker (24). The equalization filter (54) operates in response to user control to allow the user to adjust the frequency response pattern as desired. In one specific embodiment, the cellular telephone (10) includes an equalization filter table (56) for storing sets of audio frequency filter parameters, and the user merely selects one of the sets of filter parameters by pressing a corresponding button on a front control panel (11) of the cellular telephone (10). In other embodiments, the cellular telephone (10) includes an equalizer scroll bar allowing a large number of sets of filter parameters to be accessed. The equalization filter (54) and the filter table (56) may form part of a digital signal processing unit (42) also including vocoder encoders (50) and decoders (52). By providing an equalization filter (54), a cellular telephone (10) user may adjust the frequency response pattern of received signals to compensate, for example, for local noise or for hearing abnormalities to thereby allow the user to hear the other party to a telephone call more clearly. Even in the absence of any significant noise and even for a user having normal hearing, the user may still gain at least a perceived listening improvement.



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METHOD AND APPARATUS FOR APPLYING A USER SELECTED FREQUENCY RESPONSE PATTERN TO AUDIO SIGNALS PROVIDED TO A CELLULAR TELEPHONE SPEAKER

BACKGROUND OF THE INVENTION

I. Field of the Invention

The invention generally relates to cellular telephones and other mobile telephones and in particular to the audio output of a cellular telephone.

II. Description of the Related Art

In designing cellular telephones and other mobile telephones, engineers typically attempt to provide a flat frequency response pattern for audio signals provided to the speaker of the cellular telephone to thereby ensure that the voice of the other party to a telephone call is reproduced as accurately as possible. The bandwidth of audio signals transmitted within cellular systems is fairly narrow and the best frequency response pattern that can typically be achieved is one that is relatively flat within the fairly narrow bandwidth. An example of such a frequency response pattern (represented in arbitrary units) is illustrated in **FIG. 1**. As can be seen, the frequency response 2 is relatively flat within a central range of frequencies 4.

Such a flat frequency response pattern is best for many usage situations but may not be desirable for others. For example, a user may operate the cellular telephone is a noisy environment wherein the sound spectrum of the noise is skewed toward higher or lower frequencies. Examples include manufacturing environments wherein noise may be either primarily high pitched or primarily low pitched. A cellular telephone providing a fairly flat frequency response to output voice signals may not be ideal for such situations. In other situations, as a result of signal transmission problems, the received voice signal of the other party may be skewed in frequency. Indeed, the hearing range of the user may, itself, be skewed either toward higher or lower frequencies such that a flat cellular telephone output frequency response may not be ideal regardless of the presence of noise or transmission problems.

For such situations and for such users, it would be desirable to allow the user to modify the frequency response pattern of the output audio signals to yield a signal that is more easily heard. For example, if the noise

spectrum of the environment in which the cellular telephone is operated is skewed toward higher frequencies or if the received signal, as a result of transmission problems lacks sufficient higher frequencies, it would be desirable to allow the user to increase the output level of the cellular telephone speaker for the higher frequencies to thereby allow the user to hear the other party more clearly. Likewise, for a user who may not hear as well at higher frequencies than at lower frequencies, it would also be desirable to allow the user to increase the sound levels for the higher frequencies. Even in the absence of significant noise or transmission problems and even for users having normal hearing, it is still desirable to allow the user to adjust the frequency response, even if only to achieve a perceived listening improvement.

However, typical cellular telephones and other mobile telephones do not provide the user with the capability of adjusting the frequency response pattern. Accordingly, there is a need to remedy that deficiency, and it is to that end that the invention is primarily drawn.

SUMMARY OF THE INVENTION

In accordance with the invention, a cellular telephone or other mobile telephone having an audio speaker or other audio transducer is provided with a means for receiving audio signals and a means for filtering the audio signals to alter a frequency response pattern thereof. The means for filtering operates in response to user control to allow the user to adjust the frequency response pattern as desired. In this manner, the user may adjust the frequency response to compensate for local noise or transmission problems or for hearing abnormalities to thereby allow the user to hear the other party to a telephone call more clearly. At minimum, the user may gain at least a perceived listening improvement.

In an exemplary embodiment, the means filtering the audio signals operates to filter the audio signals provided to the speaker in accordance with one of a predetermined set of frequency response patterns. In one specific embodiment, the cellular telephone includes a means for storing selected sets of audio frequency filter parameters and the user selects one of the sets of filter parameters by pressing a corresponding button on a front control panel of the cellular telephone. In another embodiment, the cellular telephone includes an equalizer scroll bar allowing a larger number of sets of filter parameters to be conveniently accessed.

The invention is particularly well suited for use in cellular telephones employing digital signal processing (DSP) units which digitally process audio signals, for example, to decode received vocoder packets. Within such cellular telephones, the DSP is merely reconfigured or reprogrammed to filter the audio signals subsequent to vocoder decoding. A wide variety of other implementations are also possible.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. 1 is a graph of a typical frequency response pattern for a cellular telephone configured in accordance with the prior art;

FIG. 2 is a block diagram of a cellular telephone configured, in accordance with a first exemplary embodiment of the invention, with a set of frequency response selection buttons allowing a user to select one of a set of predetermined frequency response patterns;

FIGS. 3A - 3D are graphs illustrating exemplary frequency response patterns employed by the cellular telephone of FIG. 2;

FIG. 4 is a block diagram of pertinent internal components of the cellular telephone of FIG. 2;

FIG. 5 is a block diagram of a cellular telephone configured, in accordance with a second exemplary embodiment of the invention, with a single frequency response selection scroll bar allowing the user to scroll through a set of predetermined frequency response patterns.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to the remaining figures, exemplary embodiments of the invention will now be described. The exemplary embodiments will primarily be described with reference to block diagrams illustrating apparatus elements. It should be appreciated that not all components necessary for a complete implementation of a practical system are illustrated or described in detail. Rather, only those components necessary for a thorough understanding of the invention are illustrated and described.

FIG. 2 illustrates the external components of a cellular telephone 10 having a front control panel 11 including a keypad 12, a PHONE button 14, a SEND button 16, a display 18 and a set of equalizer buttons generally denoted 20. In a preferred embodiment, a single button is used to scroll through the equalization options. Cellular telephone 10 also includes a microphone 22, a speaker 24, and an antenna 26. In use, a user presses PHONE button 14 to activate cellular telephone 10, enters a telephone number to be dialed using keypad 12, then presses SEND button 16 to transmit the telephone number to a local cellular base station (not shown) to thereby initiate a telephone call to a remote user. Once the telephone call is connected, the user speaks through microphone 22 and hears the voice of the other party to the telephone call through speaker 24.

During the telephone call (or at any other time) the user may press one of the equalizer buttons 20. Equalizer buttons 20 control internal components (to be described in greater detail below) for adjusting the frequency response of audio signals output through speaker 24, perhaps to allow the other party to be more easily heard. Four such equalizer buttons 20 are shown in FIG. 2. The four buttons provide frequency response patterns having, respectively, enhanced high and low frequencies, enhanced high frequencies only, enhanced low frequencies only, and reduced high and low frequencies. Graphs illustrating the four frequency response patterns (in arbitrary units) are provided in FIGS. 3A - 3D. In other embodiments more or fewer equalizer buttons 20 are provided, or alternative frequency response patterns are provided, or both. In general, any desired frequency response pattern can be pre-programmed by the manufacturer. In an embodiment to be described below, the front panel of the cellular telephone includes an equalizer scroll bar allowing the user to scroll through a greater number of frequency response patterns than can be accommodated with separate equalization buttons 20 each controlling only a single corresponding frequency response pattern.

If the user presses one of buttons 20, the frequency response pattern corresponding to the pressed button is applied to audio signals provided to speaker 24, i.e. the audio signals are filtered in accordance with the selected frequency response pattern. Thereafter, the voice of the other party to the call (and all other sounds to be output through the speaker) are adjusted in accordance with the selected frequency response. Thus, for example, the user may select frequency response 27 of FIG. 3A which de-emphasizes center frequencies 28. If the user has trouble hearing higher frequencies, he or she may select frequency response 29 of FIG. 3B which enhances higher

frequencies 30. As another example, if the user is in an environment having significant low frequency noise, the user may select frequency response pattern 31 of FIG. 3C to thereby increase low frequencies 32 to compensate for the noise. As a last example, the user may select frequency response pattern 33 of FIG. 3D to de-emphasize both high frequencies 34 and low frequencies 35.

To select another frequency response pattern, the user merely presses the corresponding button 20 of the desired pattern. The previously pressed button is automatically returned to is normal position. To return to a default state wherein a relatively flat frequency response (or a default frequency response pattern) is provided, the user merely re-presses the currently de-pressed button. In an alternative embodiment, the buttons employed for selecting frequency response patterns serve other uses as well. In such an embodiment, a MODE button (not shown) is provided to allow selection of the operational mode of the buttons. In that embodiment, the buttons operate to adjust the frequency response only while placed in the appropriate mode.

Although not shown in FIG. 2, indicia may be provided on cellular telephone front control panel 11 adjacent to buttons 20 identifying the frequency response pattern associated with each button. Alternatively, or in addition, suitable identifying graphics or text may be presented on the display. In particular, the shape of the corresponding frequency response pattern may be displayed graphically within display 24. Such a graphical display is particularly desirable for embodiments wherein the buttons serve multiple purposes thereby allowing the currently selected functions of the buttons to be properly identified.

The manner by which the frequency response patterns are applied to the audio signals will now be described with reference to FIG. 4 which illustrates pertinent internal components of cellular telephone 10. More specifically, FIG. 4 illustrates that cellular telephone 10 includes a control unit 40, a DSP 42, a receiver/transmitter unit 44, a digital-to-analog (D/A) converter 46 and an analog-to-digital (A/D) converter 48. DSP 42 further includes a vocoder encoder 50, a vocoder decoder 52, an equalization filter 54 and a filter table 56. Front control panel 11, microphone 22, speaker 24 and antenna 26 are also shown symbolically in FIG. 4.

In use, as user of cellular telephone 10 speaks into microphone 22, his or her voice is routed by control unit 40 into the DSP 42 for processing therein. Vocoder encoder 50 of DSP 42 converts the voice signals into vocoder packets. The packets are encoded, by units not separately shown,

using a cellular transmission protocol such as Code Division Multiple Access (CDMA). The encoded signals are routed to receiver/transmitter 44 for transmission via antenna 26 to the local base station (not shown) and forwarded therefrom to a remote telephone (also not shown). Voice signals, in the form of encoded vocoder data packets, are received by DSP 42 either directly from receive/transmitter unit 44 or from the additional CDMA processing units not separately shown. The vocoder packets are decoded by vocoder decoder 52 of DSP 42 into a digital speech signal. The digital speech signal is routed through equalization filter 54 which, if controlled to do so, filters the speech signal in accordance with a selected set of filtering parameters read from filter table 56. The digital filtered signal is converted to an analog signal by D/A converter 46 then provided to speaker 24. All of the forgoing operations are performed under the control of control unit 40.

If the user pressed one of the equalization buttons 20 of the front control panel 11, control unit 40 receives the user selection and controls DSP 42 to adjust the frequency response accordingly via equalization filter 54. More specifically, DSP 42 reads predetermined digital filter parameters corresponding to the selected frequency response pattern from filter table 42, then equalization filter 54 filters the signal using the selected filter parameters in accordance with otherwise conventional techniques. Filter table 42 may be a ROM, RAM or similar storage device having the filter coefficients stored therein for the four frequency response patterns of FIGS. 3A - 3D. If the user does not select a specific frequency response pattern, then equalization filter 54 either does not filter the digital signal or it employs a default set of filter parameters read from filter table 56.

As noted, the resulting filtered digital speech signal is converted to an analog signal by D/A converter 46 for output to speaker 24. The user thereby hears the voice of the other party (or whatever other sounds are received by the telephone) subject to the selected frequency response pattern. The user may change the frequency response pattern any number of times during a single telephone call as needed or desired.

The filtering is applied only to the received signals. Hence, the voice of the user is not filtered for the other party, although such a feature could be provided in alternative embodiments. Additional conventional filters may be provided within the DSP, or in conjunction therewith, for performing conventional filtering operations such as noise reduction or smoothing.

Thus FIGS. 2 - 4 illustrate a first embodiment wherein separate buttons 20 are provided for each of a predetermined set of frequency

response patterns. In a second embodiment illustrated in FIG. 5, a single scroll bar 120 is provided for selecting the frequency response. The arrangement of FIG. 5 is similar to that of FIG. 2 and like components are identified with like reference numerals incremented by 100. Only pertinent differences will be described in detail. Briefly, FIG. 5 illustrates a cellular telephone 110 having a front control panel 111 including a keypad 112, a PHONE button 114, a SEND button 116, a display 118 and single scroll bar 120. Cellular telephone 110 also includes a microphone 122, a speaker 124, and an antenna 126.

Scroll bar 120 allows the user to scroll through a set of predetermined frequency response patterns. As with the embodiment of FIG. 2, the patterns are pre-stored as filter parameters in a filter table accessible by an equalization filter (neither shown in FIG. 5). A graphic is presented within display 120 (under control of an internal control unit also not shown) illustrating the currently selected frequency response pattern.

By providing scroll bar 120, rather than individual buttons, any number of different predetermined frequency response patterns may be provided. The user simply scrolls through the patterns until finding one that provides the greatest clarity or is otherwise most desirable. Deactivation of the frequency pattern adjustment is achieved by scrolling until reaching the end of the predetermined patterns, after which either no filtering or default filtering is again employed.

What has been described are exemplary embodiments of a cellular telephone configured to allow a user to select a frequency response pattern for applying to audio signals output through the speaker of telephone. In general, any desired frequency response pattern may be provided by the manufacturer merely by pre-programming the filter table with appropriate values. As noted, the filter parameters may be set to yield frequency response patterns substantially as shown in FIGS. 3A - 3D. In other cases, appropriate filter parameters may be determined empirically by testing actual users with a variety of frequency response patterns to determine which are most useful or desired. As can be appreciated, a wide range of possible techniques for determining the appropriate filter parameters for storage in the filter table may be employed consistent with the general principles of the invention. Furthermore, a filter table is not necessary. Rather, any suitable means for filtering may be employed. For example, the audio signals subsequent to conversion to analog signals may be routed through electronic circuitry configured to directly vary the electrical characteristics of the audio signals.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

WE CLAIM:

CLAIMS

1. In a cellular telephone having a speaker, an apparatus for adjusting a frequency response pattern of audio signals provided to said speaker, said apparatus comprising:

means for receiving said audio signals; and

means for filtering said audio signals to alter said frequency response pattern thereof.

2. The apparatus of claim 1 wherein said means for filtering operates to filter said audio signals provided to said speaker in accordance with one of a predetermined set of frequency response patterns.

3. The apparatus of claim 2 wherein said predetermined set of frequency response patterns includes patterns selected from a group consisting of enhanced high and low frequencies, enhanced high frequencies only, enhanced low frequencies only, and reduced high and low frequencies.

4. The apparatus of claim 1 wherein said means for filtering operates on digital signals output from a vocoder decoder of said cellular telephone.

5. The apparatus of claim 4, further including:

means for receiving a user selection of one of said set of predetermined frequency response patterns.

6. The apparatus of claim 5 further including:

means for storing selected sets of filter parameters; and

wherein said means for receiving a user selection operates to receive an identification of a selected one of said sets of filter parameters.

7. The apparatus of claim 6, wherein said means for receiving a user selection includes

a set of equalization buttons; and

a control unit configured to select one of said predetermined frequency response patterns in response to manual activation of a corresponding one of said equalization buttons.

8. The apparatus of claim 6, wherein said means for receiving a user selection includes

a scroll bar; and

a control unit configured to sequentially select one of said predetermined frequency response patterns in response to repeated manual activation of said scroll bar.

9. In a cellular telephone having an audio speaker, a method for adjusting a frequency response pattern of audio signals provided to said speaker, said method comprising the steps of:

receiving said audio signals; and

filtering said audio signals to alter said frequency response pattern thereof.

10. The method of claim 9 wherein said step of filtering is performed to filter said audio signals provided to said speaker in accordance with one of a predetermined set of frequency response patterns.

11. The method of claim 10 wherein said predetermined set of frequency response patterns includes patterns selected from a group consisting of enhanced high and low frequencies, enhanced high frequencies only, enhanced low frequencies only, and reduced high and low frequencies.

12. The method of claim 9 wherein said step of filtering is performed on digital signals output from a vocoder decoder of said cellular telephone.

13. The method of claim 11, further including the step of:

receiving a user selection of one of said set of predetermined frequency response patterns.

14. The method of claim 13 further including the initial step of:

storing selected sets of filter parameters; and

wherein said step of receiving a user selection is performed to receive an identification of a selected one of said sets of stored filter parameters.

15. A cellular telephone comprising:

an antenna;

a receiver connected to said antenna;

an audio transducer;

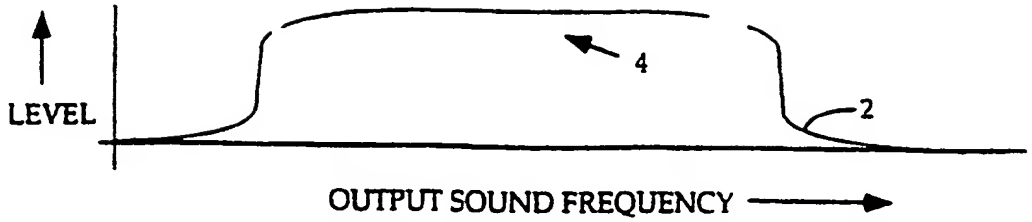
a digital-to-analog converter connected to said transducer; and

a digital signal processor (DSP), connected to said receiver and said digital-to-analog converter, for processing a signal received from said antenna by said receiver for output to said transducer, said DSP including

a vocoder decoder for decoding vocoder packets within said signal,

a filter table for storing sets of predetermined audio equalization filter parameters, and

an equalization filter for filtering said signals in accordance with one of said sets of predetermined audio equalization filter parameters stored in said filter table.



(PRIOR ART)

FIG. 1

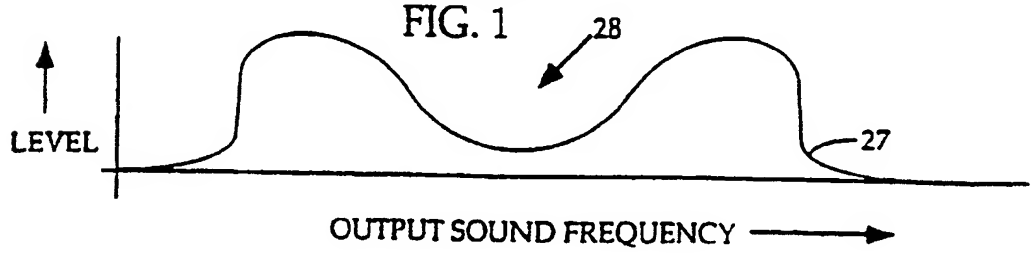


FIG. 3A

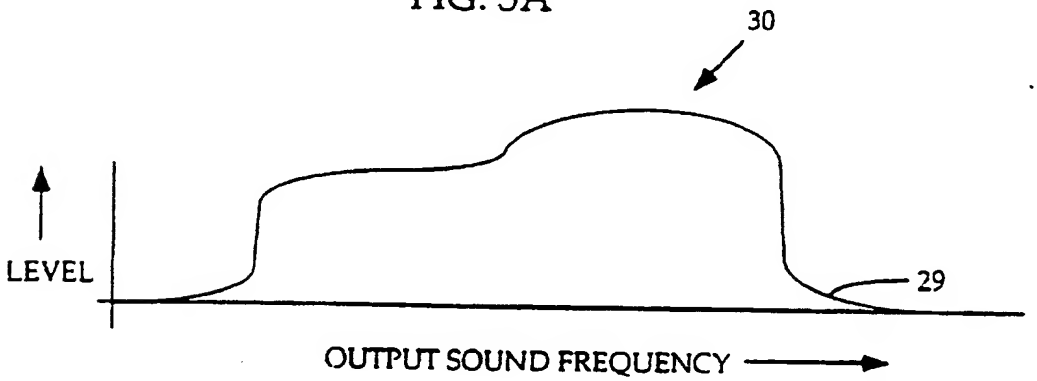


FIG. 3B

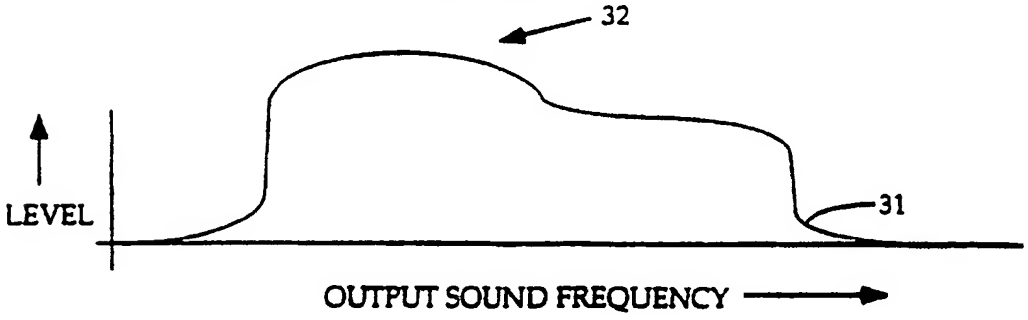


FIG. 3C

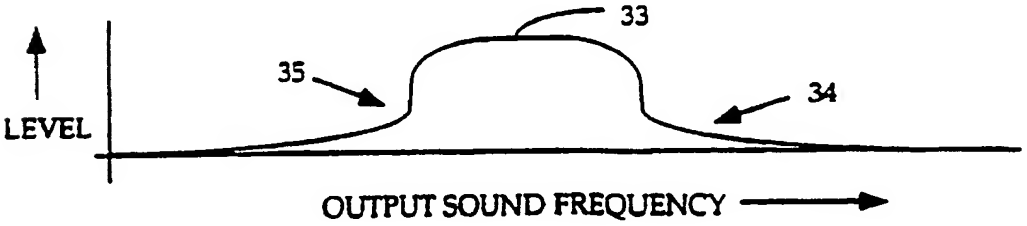


FIG. 3D

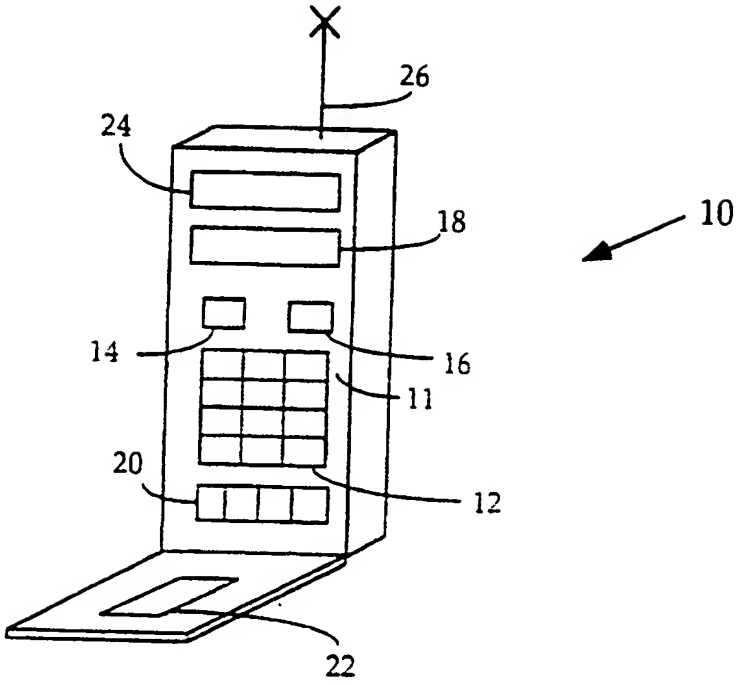
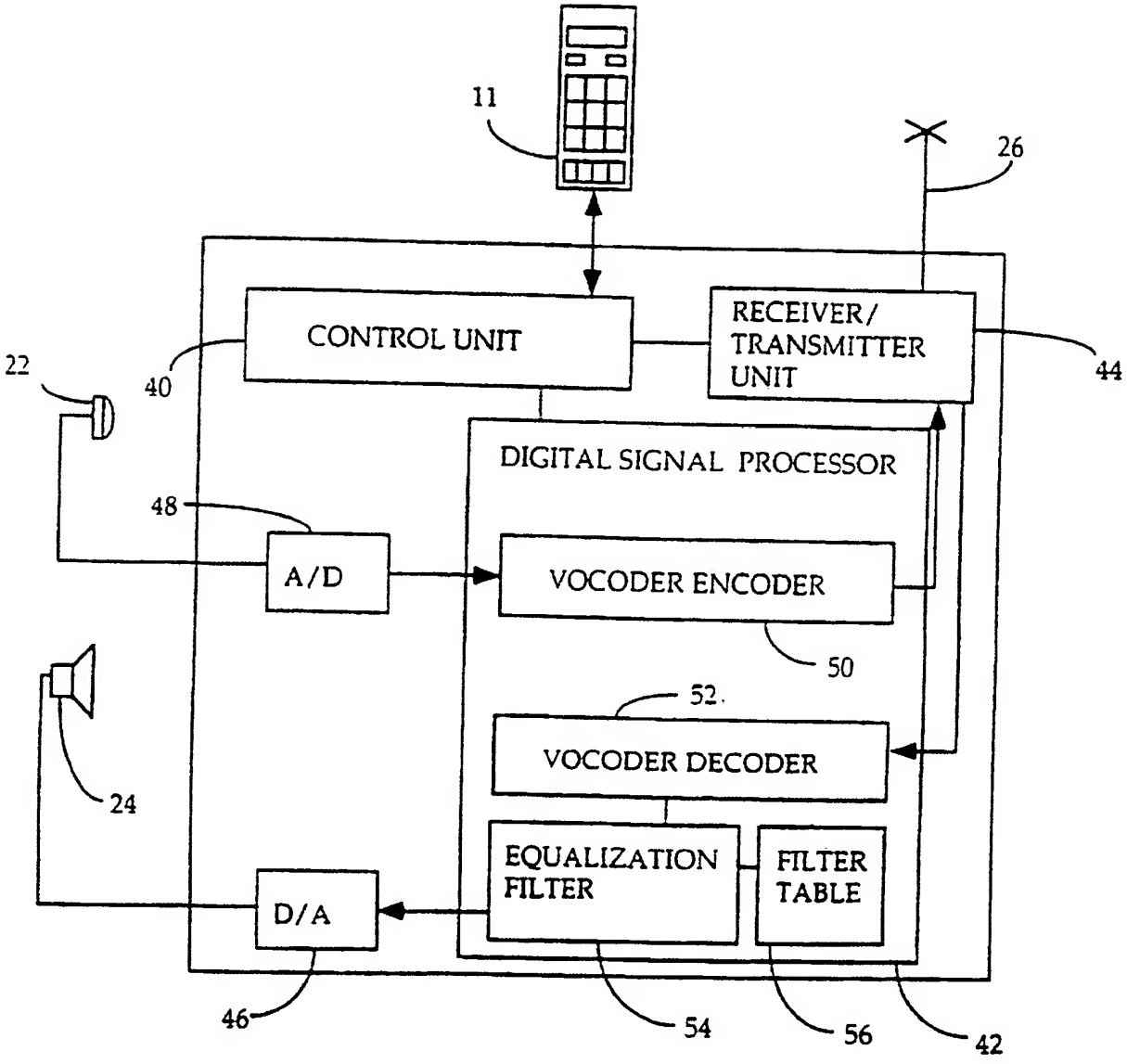


FIG. 2


11
26
CONTROL UNIT
RECEIVER/
TRANSMITTER
UNIT
44
40
22
DIGITAL SIGNAL PROCESSOR
48
A/D
VOCODER ENCODER
50
52
VOCODER DECODER
24
EQUALIZATION
FILTER
FILTER
TABLE
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46
54
56
42
10

FIG. 4

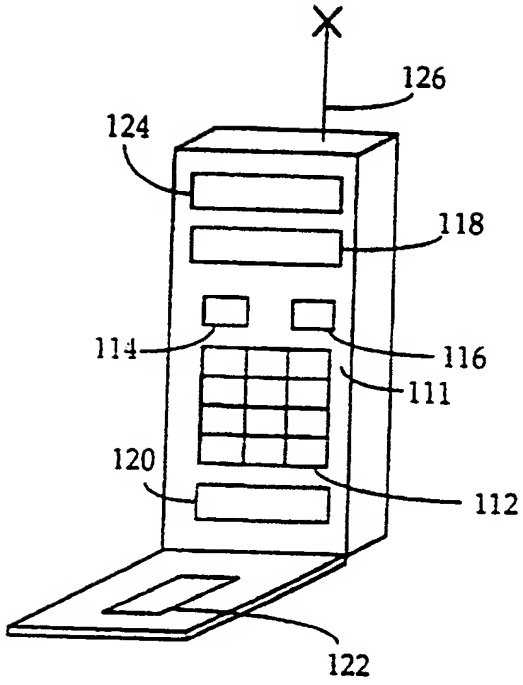

FIG. 5

INTERNATIONAL SEARCH REPORT

Inte. .onal Application No
PCT/US 97/13593

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04M1/60

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category '	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 674 415 A (NIPPON ELECTRIC CO) 27 September 1995 see column 1, line 1 - line 6 see column 1, line 25 - column 2, line 35 ---	1-3,9-11
X	PATENT ABSTRACTS OF JAPAN vol. 013, no. 366 (E-806), 15 August 1989 & JP 01 123554 A (TOSHIBA CORP;OTHERS: 01), 16 May 1989, see abstract ---	1,9 2,5,10, 13,15
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 240 (E-1545), 9 May 1994 & JP 06 030090 A (MITSUBISHI ELECTRIC CORP), 4 February 1994, see abstract --- -/--	1,9 2,3,15

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
10 November 1997	24/11/1997

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Goulding, C

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inter .onal Application No
PCT/US 97/13593

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category '	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 596 623 A (AMERICAN TELEPHONE & TELEGRAPH) 11 May 1994 see abstract see column 4, line 11 - line 48	1-15
A	FR 2 633 125 A (SGS THOMSON MICROELECTRONICS) 22 December 1989 see page 2, line 28 - page 3, line 14	1-15
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